VOCAL NOISE CANCELLATION FROM RESPIRATORY SOUNDS

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Abstract-**Although background noise cancellation for speech or electrocardiographic recording is well established, however when the background noise contains vocal noises and the main signal is a breath sound, the problem becomes challenging as the signal and noise are no longer uncorrelated. In this paper, a technique for detecting the vocal noise within a breath sound and then removing it without hampering the main components of the breath sound is discussed. The results of this study show that the developed technique is successful and feasible in time domain. This technique may also be used to detect and separate wheezes from breath sounds in clinical assessments.**
Keywords **- respiratory sounds, noise cancellation, vocal noise, wheezes.**

I. INTRODUCTION

One of the major problems during any respiratory sound recording is the extra noise other than breath sounds. These extra noises include background noise coming from the surrounding environment and also the vocal noises originating from people talking in the vicinity of the subject or from the wheezes or any vocal noise that the subject may make. During a respiratory assessment in many well-equipped labs, the recording is being done in a sound proof chamber to avoid all external noises. However, during feeding assessment, where a recording of respiratory sounds still of interest, it is not possible to avoid external noises, and also the noise of wheezes is inherent regardless of the recording situation.

Background noise cancellation in acoustical recording is well established by using an auxiliary sensor to record background noise and running an adaptive filter either on real time or after recording [1]. However, the main assumption in this method is that the background noise and the main signal are uncorrelated, which is true for non-vocal background noise but not for vocal noise in the vicinity of the subject. Therefore, a different method should be sought for separating the vocal noise from the breath sound and that was the main objective of this research.

The main objective of this study was to develop a method to remove the vocal noises from the breath sounds without hampering the main characteristic features of the breath sound. The method of using an auxiliary sensor to record vocal background noise and adaptive cancellation, was also studied. However, as expected the adaptive noise cancellation failed when the background noise included vocal noises.

II. METHOD

Experimental procedure
Two healthy men (22 and 45 years old) volunteered for the experiments of this study. The tracheal breath sound was recorded by placing a Siemens accelerometer (EMT25) on the suprasternal notch of the subject. An auxiliary sensor of the same type was hung in the air within 10 cm of the sensor on the subject. The subject was asked to breathe normal and after 5 breaths, another person repeated a sentence three times while the subject was breathing normal. At the end, the subject was asked to hold his breath with a closed glottis for 10 seconds. The signals from the two sensors were amplified and band pass filtered from 20-5000 Hz and digitized with a 10240 sampling rate. This experiment was repeated 5 times.

Signal Processing
The spectrogram of each signal was determined by calculating the power spectrum of every 100 ms segment of the data with 50% overlap between the adjacent segments and applying Hanning window to each segment. Figure 1 shows the spectrograms of a signal recorded by the accelerometer on the subject and the noise recorded by the auxiliary accelerometer, respectively. At first, correlation of the breath sound and the vocal noise was investigated. Figure 2, shows the correlation of a noise-free breath segment recorded from accelerometer on the subject and the noise signal recorded with the auxiliary accelerometer. As it can be seen, there is a high correlation between the two signals and therefore it is not surprising that the adaptive filtering techniques for noise cancellation would fail in this case. Therefore, in order to establish a technique to remove the noise from signal the power spectrum of a signal with noise was considered and compared to that of a noise-free breath segment (Figure 3). As it can be observed, the effect of vocal noise on the spectrum of the breath sound is to cause high spectral peaks in several consecutive segments, while a noise free breath sound has almost a monotonically decreasing power spectrum. Since breath sound signals recorded at trachea has appreciable components mostly below 1200 Hz [2], the signal was first low-pass filtered with a cut off frequency of 1200 Hz and then a running window was used to detect the spectral peaks due to the vocal noise. The length of this window was considered to be 250 Hz.

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Abstract

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The criterion to detect the spectral peaks due to noise was determined as the following: if the sound intensity of the signal at a frequency, f, was at least 5 dB more than the expected intensity, then that frequency contained noise that had to be removed. The expected intensity was determined by fitting a line to the spectrum of each sound segment (100 ms in duration). This criterion was applied to all successive sound segments to detect all the spectral peaks due to the vocal noise. Then successive notch filters were applied at those particular frequencies that contained spectral peaks. The digital notch filters were designed by using 1st order Butterworth filter. The order of the filter was chosen as 1, because in most cases the power of the noise was not more 15 dB higher than the signal, therefore increasing the order would have caused a deeper valley in place of the peak in the filtered signal. The duration of the stop band of the notch filters, however, was determined by the width of the peak, which was defined from all the frequencies that their power was above the expected power plus 5 dB.

Although the spectrum of each sound segment was calculated in order to detect the exact frequencies for notch filters, however, the notch filters were applied directly to the time domain signal in order to be able to replay and listen to the breath sounds for further checking.

III. RESULTS

The developed technique of automatic detection of spectral peaks due to noise and applying successive notch filters to the sound plus noise was successful to remove the vocal noise without hampering the main components of the breath sound signal. Figure 4 shows an inspiration sound before and after filtering. Listening to the breath sounds after filtering confirmed that the signal had become free of noise while the main audible components of the breath sounds was heard intact.

IV. DISCUSSION

Although the proposed technique in removing vocal noises from the breath sounds was successful in terms of removing noise and even a trained human ear was not able to detect any deficiency in the filtered signal, however, as can be seen in Figure 4, applying the notch filters cause some valleys in place of original peaks that ideally is not desirable. One way to overcome this problem is to interpolate the spectrum in the vicinity of the notch frequency and then reconstruct the signal in time domain. However, the goal of this study was to be able to apply the technique all in time domain and avoid reconstruction of the signal from frequency to time domain as it will be at the price of loosing some other information. Other solutions to remedy this inherent problem of notch filtering are still under investigation.

In this study, the expected sound intensity of each segment was found by fitting a line to the spectrum of the segment, which is better than applying a moving average that is essentially applying a polynomial of degree 0 to the data. However, one may still argue to increase the degree of the polynomial from 1, which is fitting a line to the data, to 2 or higher for a better curve fitting at the price of more calculation. The results of this study however show that fitting a line is sufficient to provide a reliable expected sound intensity for the base of comparison with the spectral peaks.

While the proposed technique in this paper was basically developed for the sake of removing external vocal noises, it can also be used for detecting and removing wheezes from breath sounds in the clinical assessments since wheezes have the same characteristics as vocal noises.

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[2] H. Pasterkamp, S. Kraman and G. Wodicka, "Respiratory Sounds, Advances Beyond the Stethoscope", Am J Respir Crit Care Med, Vol. 1156. Pp. 974-987, 1997.

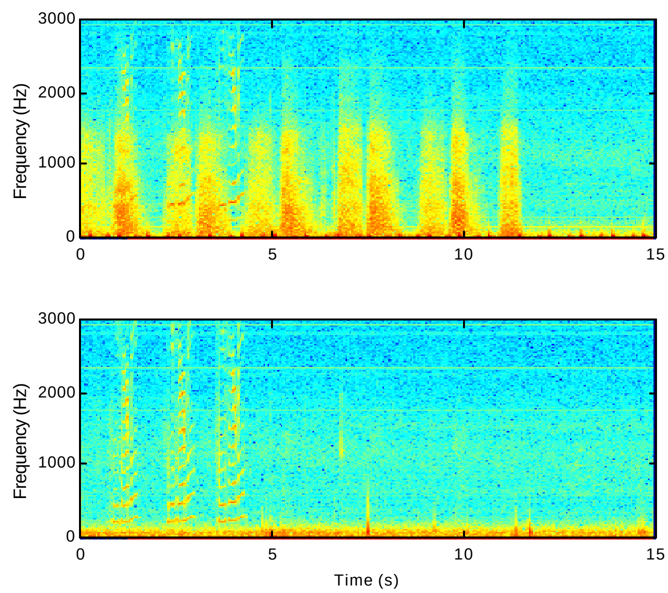

Figure1. A typical example of the tracheal breath sound plus noise recorded by the accelerometer on the subject (the top graph) and the noise recorded by the auxiliary accelerometer (the bottom graph).

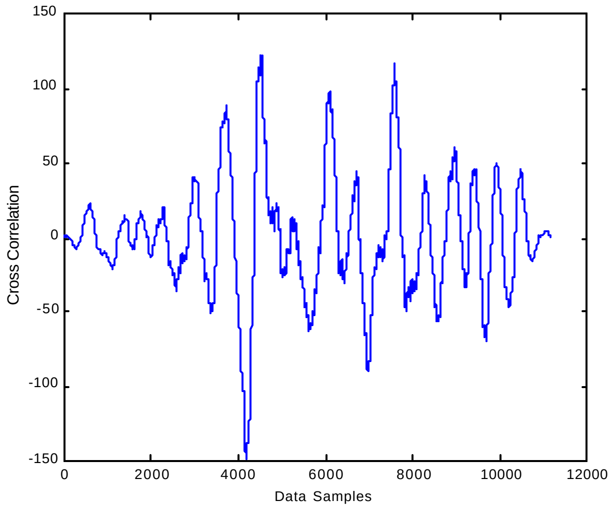

Figure 2. Cross correlation between breath sound and vocal noise.

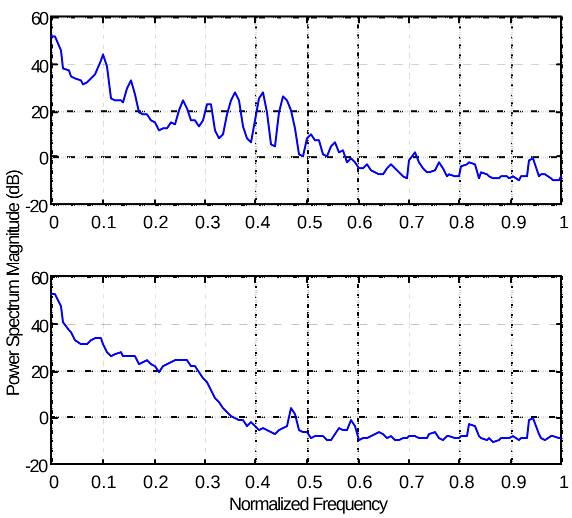

Figure 3. Power spectrum of an inspiration with noise (the topgraph) and an inspiration free of vocal noise (the bottom graph)

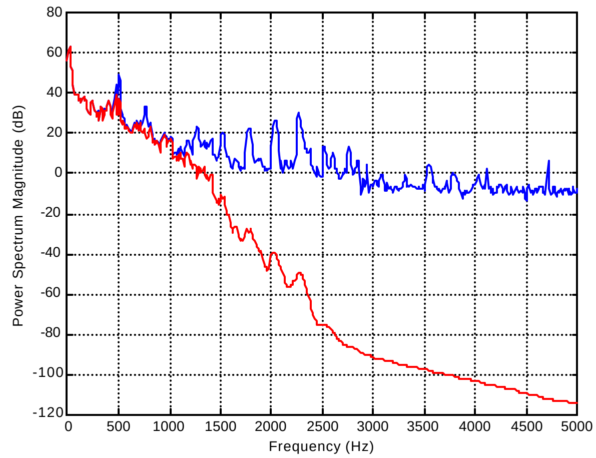

Figure 4. Power spectrum of an inspiration with noise before (blue) and after (red) filtering.